Case Report

ANNALS OF MEDICINE & SURGERY

OPEN

Primary gastrointestinal stromal tumor of the liver: a case report

Anh Tuan Pham, PhD[a], Anh The Pham, MD, PhD[b,*], Cuong Manh Truong, MD[b], Thang Huu Nguyen, MD[a], Phuong Huy Trinh, MD[b]

Introduction and importance: Primary gastrointestinal stromal tumors of the liver are exceedingly rare entities, presenting diagnostic and therapeutic challenges. The authors present a case of a 64-year-old male with a primary gastrointestinal stromal tumor (GIST) of the liver, emphasizing the importance of comprehensive diagnostic evaluation and multidisciplinary management in such uncommon cases.

Case presentation: The patient presented with persistent hypochondriac pain, leading to the discovery of a hepatic mass. Diagnostic work-ups, including imaging studies and biopsy, confirmed the diagnosis of primary GIST in the liver. Following thorough multidisciplinary consultation, the patient underwent right anterior segmentectomy of the liver, performed by our experienced surgeon. Postoperative pathology confirmed the diagnosis of GIST, and the patient was advised to use adjuvant imatinib.

Clinical discussion: Primary GISTs of the liver pose diagnostic challenges due to their rarity and varied clinical presentations. Imaging modalities, immunohistochemistry, and molecular genotyping are crucial in accurate diagnosis and treatment planning. Surgical resection remains the cornerstone of treatment for localized GISTs, with adjuvant therapy considered based on recurrence risk factors and molecular characteristics.

Conclusion: This case highlights the need for multidisciplinary consultation in managing primary GISTs of the liver. Accurate diagnosis, surgical expertise, and personalized adjuvant therapy are crucial for better patient outcomes. Further research is necessary to enhance our understanding of prognostic factors and treatment strategies for these rare tumors.

Keywords: adjuvant therapy, gastrointestinal stromal tumor, hepatectomy

Introduction

Gastrointestinal stromal tumors (GISTs) are rare mesenchymal neoplasms that most commonly arise in the gastrointestinal (GI) tract, with the stomach being the predominant site[1–5]. They are thought to originate from the interstitial cells of Cajal (ICCs), which play a crucial role in regulating peristalsis[6]. While GISTs are generally rare, the primary GIST of the liver is an exceptionally uncommon entity[5]. We herein present a case of primary GIST of the liver, treated at Vietnam National Cancer Hospital, and discuss the clinical presentation, diagnostic evaluation, treatment strategy, and outcome of these cases in the context of current surgical literature and standards of care. This case report is compliant with the SCARE Guidelines 2023[7].

HIGHLIGHTS

- Primary gastrointestinal stromal tumors (GISTs) of the liver are exceedingly rare entities, presenting diagnostic and therapeutic challenges.
- We present a case of a 64-year-old male with a primary GIST of the liver, emphasizing the importance of comprehensive diagnostic evaluation and multidisciplinary management in such uncommon cases.

Case presentation

The patient was a 64-year-old male with an unremarkable medical history. In December 2023, he presented to our hospital with persistent pain in his right hypochondriac region for the past 2 months, which had worsened. Upon admission, he weighed 54 kg, had a height of 165 cm, and had an Eastern Cooperative Oncology Group (ECOG) PS of 0. He reported no fever. On examination, his abdomen was soft without any reactive responses.

The hemoglobin (156 g/l), the number of white blood cells (5.81 10^9/l), and platelets (286 10^9/l) were in normal ranges. The prothrombin time (10.1 s), the level of glucose (5.15 mmol/l), Aspartate aminotransferase (22.8 U/l), Alanine Aminotransferase (34.8 U/l), total bilirubin (11.3 µmol/l), direct bilirubin (1.6 µmol/l) and albumin (41 g/l) were also normal. Among the tumor

Departments of [a]Optimal Clinical Care and [b]Hepatobiliary and Pancreatic Surgery, Vietnam National Cancer Hospital, 30 Cau Buou, Tan Trieu, Hanoi, Vietnam

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Department of Hepatobiliary and Pancreatic Surgery, Vietnam National Cancer Hospital, 30 Cau Buou Street, Hanoi 12500, Vietnam. Tel.: +84 912 118 212. E-mail: theanhbenhvienk@gmail.com (A.T. Pham).*

Annals of Medicine & Surgery (2024) 86:4284–4290

Received 22 March 2024; Accepted 19 May 2024

Published online 28 May 2024

http://dx.doi.org/10.1097/MS9.0000000000002228

markers, the levels of CA 19-9 (27.3 U/ml), Carcinoembryonic antigen (3,36 ng/ml), and Alpha-fetoprotein (7.0 ng/ml) were within the average limits. The patient tested negative for both hepatitis B and hepatitis C infections.

A hypoechoic mass within liver subsegment VIII measuring 28 × 32 mm with clear borders was observed on abdominal ultrasound. Subsequent MRI revealed a lesion measuring 26 × 28 mm within the same subsegment of the liver parenchyma, characterized by compact edges, increased signal on T2 and STIR sequences, limited diffusion, and minimal enhancement post-injection (Fig. 1). Esophagogastroduodenoscopy and colorectal endoscopy revealed no abnormalities. Besides the 26 × 29 mm lesion in the subsegment VIII, which exhibited robust enhancement on arterial phase imaging, no additional lesions were detected on whole-body computed tomography (CT) (Fig. 2). A biopsy of the liver tumor was conducted (Fig. 3), followed by immunohistochemical staining, indicating GIST with CD117 (+), DOG-1 (+), CD34(+), and S100 (–) (Fig. 4). After a thorough multidisciplinary consultation, the patient was diagnosed with a "Primary gastrointestinal stromal tumor of the liver" and was recommended for right anterior segmentectomy of the liver. The patient agreed to that approach and was scheduled for surgery on 23 February 2024.

The leading surgeon was a highly trained and experienced surgeon. Firstly, a J-shaped incision beneath the right rib was performed. Intraoperative findings showed a dry abdomen and a smooth peritoneum. On examination, the liver had two soft lobes; the anterior segment had a tumor of size 3 × 3 cm with firm density, wholly located in the liver parenchyma; the remaining liver segments showed no abnormal mass. The gallbladder was excised, and its duct was tied with a linen thread. Subsequently, the anterior liver segment was excised utilizing an ultrasonic knife, clips, and 4/0 and 5/0 prolene sutures. The entire liver pedicle was clamped twice, for 7 and 19 min, with a 5-min interval between each clamping. Two drains were placed in the hepatectomy area and the right subdiaphragmatic region before closing the abdomen in two layers. The surgery ended at 4:40 P. M on 23 February 2024, with a total surgery time of 2 h and 40 min. The surgery proceeded well, and no intraoperative blood transfusion was required.

The postoperative pathology result was consistent with the preoperative one, which revealed a 3cm tumor of GIST with low grade according to the Miettinen classification and no abnormal findings in the gallbladder. Surgical margins that were measured on pathology were 1cm (Fig. 5).

Currently, 4 weeks after surgery, he is being considered for adjuvant imatinib therapy.

Discussion

Epidemiology

GISTs are uncommon tumors, constituting about 1–2% of primary GI tract cancers[1,2]. Despite their infrequency, GISTs are the predominant mesenchymal (non-epithelial) neoplasms within the GI tract[1–3]. A systematic review of population-based studies focusing on GIST, conducted between January 2000 and December 2014 and encompassing over 13 550 patients from 19 different countries, revealed that the typical age of patients diagnosed with GIST was in their mid-60s, gender distribution was pretty equal, approximately 18% (5–40%) of patients were

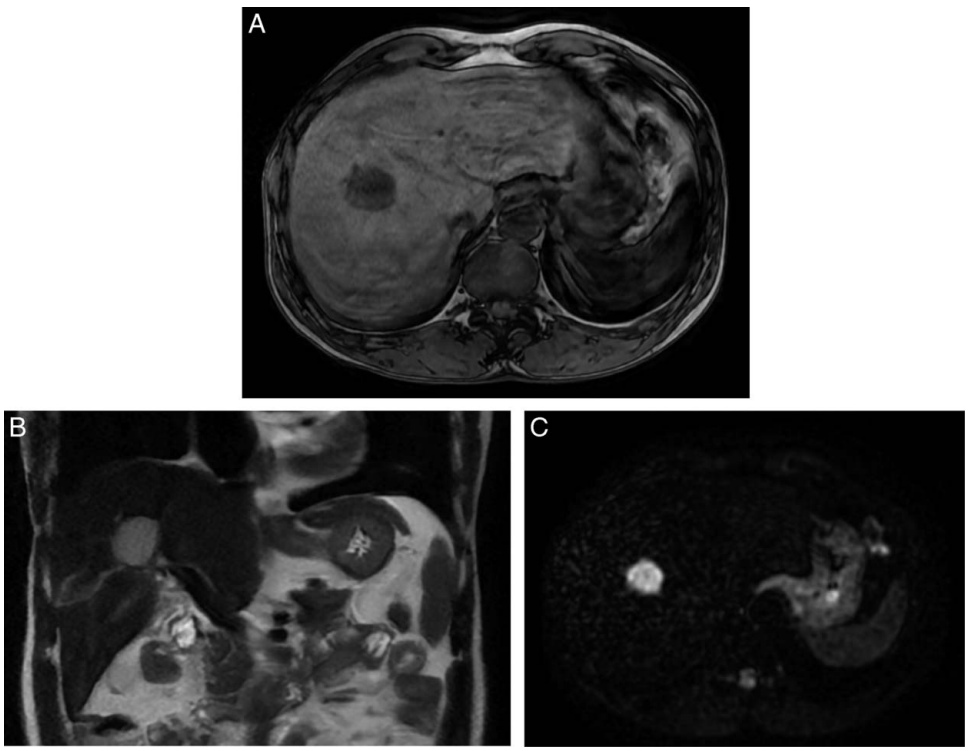

Figure 1. MRI revealed a 26 x 28 mm mass in the subsegment VIII, characterized by compact edges, decreased signal on T1 sequence (A), slightly increased signal on T2 sequence (B) and robust increased signal on diffusion-weighted imaging sequence (C).

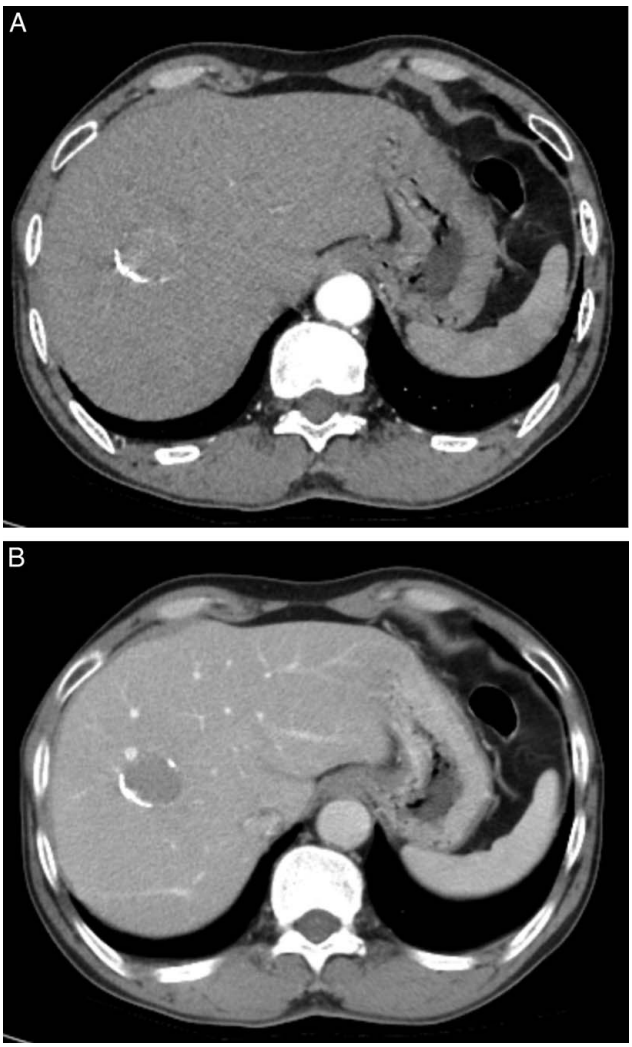

Figure 2. Computed tomography scan revealed a 26 × 29 mm mass in subsegment VIII, exhibiting enhancement during arterial phase imaging with peripheral calcification (similar to liver parenchyma) (A), and subsequent drug withdrawal during venous phase imaging (B).

incidentally diagnosed, the stomach was the most common location (55.6%), followed by the small bowel (31.8%), colorectal area (6.0%), various other locations (5.5%), and the esophagus (0.7%), and most studies indicated an incidence rate of 10-15 cases per million per year[4]. The primary GIST of the liver is a sporadic tumor. According to a literature review by Qian *et al*.[5], only 35 cases had ever been reported in online databases, including PubMed and China National Knowledge Internet, with no restrictions on publication dates until 1 December 2019.

Clinical presentation

Some patients with primary hepatic GISTs might not experience apparent symptoms but discover a liver mass unexpectedly during routine check-ups or imaging scans, subsequently confirmed through diagnostic tests. In the literature review by Qian and colleagues, which includes 35 case reports up to 2019, ~18% (range: 5–40%) of patients were diagnosed by chance. When symptoms do occur, they can resemble those of chronic liver disease, with abdominal pain and a palpable abdominal mass being the most common. Our patient presented to our hospital with persistent pain in his right hypochondriac region lasting for two months. Other gastrointestinal symptoms may include discomfort, indigestion, and bloating. Notably, some patients may experience significant weight loss or difficulty breathing due to a large tumor causing compression in the advanced stages[8–10]. As the tumor grows, there is also a risk of rupture and bleeding, as demonstrated in the case report by Hon Ting Lok[11].

Imaging

CT imaging of GISTs typically reveals masses with soft tissue density, often with central areas of reduced density indicating necrosis, particularly in more extensive tumors. This necrosis can occasionally manifest as fluid-fluid levels within the mass. The presence of non-enhancing central necrotic areas can aid in identification. The Torricelli-Bernoulli sign, characterized by deep crescent-shaped ulceration with an internal air-fluid level, may also be observed[12]. Enhancement patterns on CT typically show peripheral enhancement due to central necrosis, while calcification is uncommon[13]. On arterial phase CT imaging, our patient exhibited a 26 × 29 mm lesion located in subsegment VIII, displaying robust enhancement and clear margins.

MRI further illustrates GIST characteristics, with appearances varying based on necrosis, hemorrhagic, and cystic changes[14]. Small and large lesions exhibit differing imaging characteristics, with T1-weighted images showing low signal intensity in the solid component while T2-weighted images demonstrating high signal intensity. Contrast-enhanced T1-

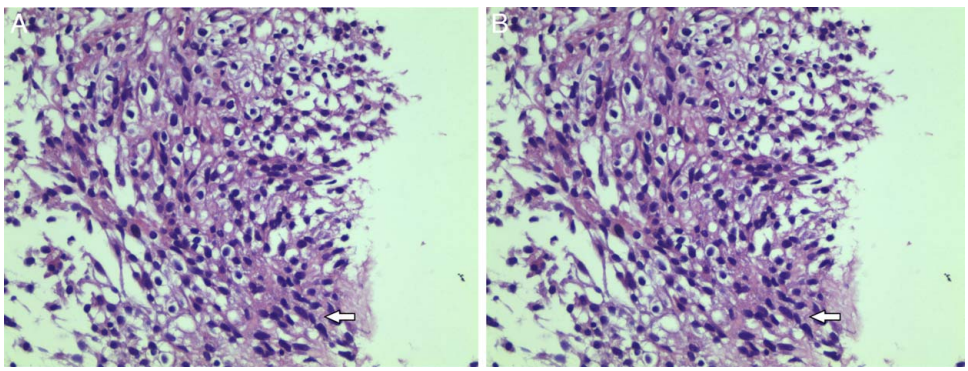

Figure 3. Hematoxylin and eosin staining of liver biopsy specimen revealing a stromal tumor composed of spindle cells [magnification: (A):200 ×; (B) 400 ×].

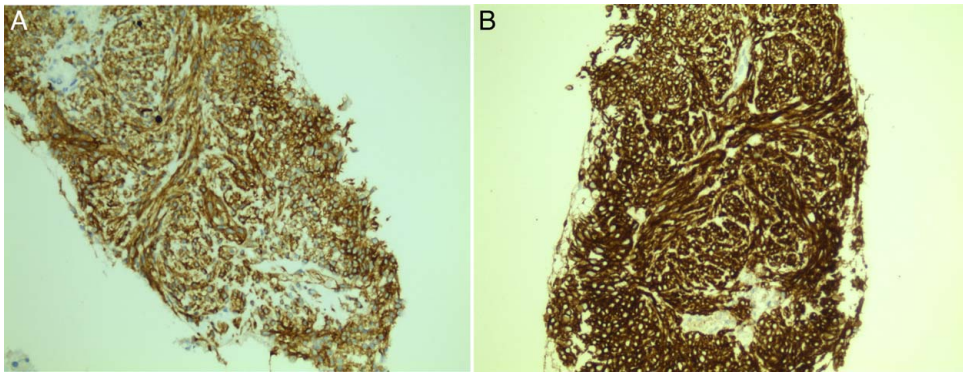

Figure 4. Immunohistochemistry staining with the antibody to CD117 (A) and DOG-1 (B) shows diffuse cytoplasmic staining of almost all tumor cells (magnification 200×).

weighted images reveal heterogeneous gradual enhancement in more extensive lesions and substantial arterial enhancement persisting in smaller lesions. Diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping typically portray high DWI signal and low ADC signal, respectively, with lower ADC values associated with high-risk tumors[14]. In our case, magnetic resonance imaging revealed a lesion measuring 26×28 mm within the subsegment VIII of the liver parenchyma, characterized by compact edges, increased signal on T2 and STIR sequences, limited diffusion, and minimal enhancement post-injection.

Figure 5. Photograph showing the gross appearance of the dissected tumor. On evaluation, the hepatic tumor was well circumscribed and measured 4×3×2.8 cm.

GISTs are fluorodeoxyglucose (FDG)-avid tumors, and F-18 FDG positron emission tomography/CT (PET/CT) can be used for initial staging and treatment response assessment[15] and in a study published in the Journal of Gastroenterology and Hepatology, Kim and Lee investigated the utility of F-18 FDG PET or PET/CT in predicting the malignant potential of GIST. A systematic review and meta-analysis of seven studies involving 188 patients found that F-18 FDG PET or PET/CT demonstrated good sensitivity and specificity in this regard, with a pooled sensitivity of 0.88 and a specificity of 0.88[16].

Diagnostic procedures for conventional GISTs

Upper endoscopy with endoscopic ultrasound (EUS) is the preferred diagnostic approach for characterizing suspected upper gastrointestinal stromal tumors (GISTs) involving the stomach, small intestine, or esophagus. GISTs typically present as submucosal masses with smooth margins, sometimes with central ulceration. EUS distinguishes intramural from extramural tumors by identifying the layer of origin, with GISTs often appearing hypoechoic and homogeneous. It aids in guided tissue acquisition for diagnostic studies. Colonoscopy is utilized to identify masses suspicious of GIST in the colon, rectum, and anus, although colorectal GISTs are sporadic. Small colonic polypoid masses can be resected endoscopically, but larger or subepithelial masses may require surgical resection or sampling using EUS-guided biopsy.

Cellular morphology

The cellular structure of gastrointestinal stromal tumors (GISTs) varies, ranging from predominantly spindle-shaped to epithelioid. Typically, these tumors fall into one of three main categories: spindle cell type, epithelioid type, and mixed type. Spindle cell GISTs, accounting for about 70% of cases, consist of relatively uniform eosinophilic cells arranged in short fascicles or whorls[6]. Compared to leiomyomas, these cells have paler eosinophilic cytoplasm with a fibrillary appearance, and the nuclei are usually uniform. Stromal collagen is minimal in most cases, and stromal hemorrhage is common, while marked cytologic pleomorphism is uncommon. Epithelioid GISTs, making up ~20% of cases, are rounded cells with variable eosinophilic or clear cytoplasm[17]. They often have round to oval nuclei with

vesicular chromatin and may exhibit nested architecture, potentially leading to confusion with epithelial or melanocytic neoplasms. Notably, epithelioid GISTs are more commonly KIT-expression negative, often harbor platelet-derived growth factor receptor alpha (PDGFRA) mutations, and are frequently found in the stomach[18]. Mixed-type GISTs may display areas of sudden transition between spindle and epithelioid regions or intricate mingling of both cell types throughout.

Immunohistochemistry (IHC)

IHC staining is crucial in distinguishing gastrointestinal stromal tumors (GISTs) from other subepithelial tumors within the gastrointestinal tract. The primary diagnostic marker for GISTs is the nearly universal overexpression of the receptor tyrosine kinase KIT (CD117), readily detected by positive IHC staining. However, the correlation between KIT protein expression and KIT mutations in GISTs is more complex. While ~95% of GISTs exhibit positive KIT expression on IHC, some tumors that express KIT lack detectable KIT mutations, particularly in pediatric cases and those associated with neurofibromatosis type 1 (NF1)[19–23]. Conversely, a small subset of GISTs lacks KIT expression on IHC, with some harboring activating mutations in the PDGFRA gene[24,25]. Immunohistochemical markers such as DOG-1 and PKC-theta have also emerged as useful diagnostic tools for GISTs, regardless of KIT or PDGFRA mutational status[26,27]. Other markers, including CD34, smooth muscle actin, S100 protein, desmin, and keratin, may also aid in the diagnosis, with varying degrees of positivity observed in GISTs[6,25,28]. Immunohistochemical staining of our patient indicated GIST with CD117 (+); DOG-1 (+); CD34(+); S100 (–).

Diagnosis

Diagnosing primary GISTs in the liver requires a comprehensive approach. Firstly, evidence of pathology and immunohistochemistry of the liver lesions is essential for accurate diagnosis. Secondly, it is crucial to ensure that no other lesions are present except in the liver, as conventional GIST locations primarily involve the GI tract. This involves utilizing various imaging modalities such as CT, MRI, PET, and endoscopic procedures, including upper endoscopy and colonoscopy, to thoroughly evaluate the GI tract for any additional lesions. In our specific case, imaging studies revealed a liver mass, and subsequent pathological examination confirmed the diagnosis of GIST. Notably, preoperative gastroscopy, colonoscopy, and imaging studies did not detect any other GISTs except for the hepatic tumor, supporting the diagnosis of primary liver GIST. This underscores the importance of a multidisciplinary approach and comprehensive evaluation in diagnosing and managing rare entities like primary hepatic GISTs.

Treatment

The latest clinical practice guidelines from The National Comprehensive Cancer Network (NCCN) and the European Society for Medical Oncology (ESMO) are aligned in the management of GISTs[29,30]. Surgery remains the cornerstone in the treatment of resectable GISTs. For localized GISTs larger than or equal to 2 cm, resection is recommended, although the approach for smaller incidental tumors should be individualized due to a lack of consensus. Particularly for potentially resectable gastric and intestinal GISTs, segmental visceral resection is preferred over peritumoral resection, with no requirement for regional lymphadenectomy. This surgical strategy aims to achieve complete tumor removal while preserving organ function and minimizing surgical morbidity.

Neoadjuvant therapy presents a valuable option, especially for locally advanced or borderline resectable GISTs. Patients with KIT or non-D842V PDGFRA mutated GISTs, who are non-metastatic, often benefit from neoadjuvant therapy. This approach, typically involving imatinib, facilitates resection and reduces surgical complications. However, for tumors with PDGFRA D842V mutations or those classified as wild-type (neither KIT nor PDGFRA mutations), direct surgery without neoadjuvant therapy is preferred, ensuring timely intervention.

Adjuvant therapy plays a crucial role in reducing recurrence risk following surgical resection, particularly in high-risk and intermediate-risk GISTs. Imatinib is commonly employed post-operatively for at least 3 years, guided by molecular genotyping to identify appropriate candidates. Higher doses for specific mutations, such as KIT exon nine, may be considered. However, for low-risk or very low-risk GISTs, surveillance alone may suffice without adjuvant therapy.

In our institution, accessing KIT or PDGFRA mutations is not feasible, and our patients cannot afford these tests outside of health insurance coverage. Consequently, we must assess the likelihood of our patient being a suitable candidate for adjuvant treatment of imatinib. Firstly, among 95% of GISTs with positive KIT expression on IHC, some tumors lack detectable KIT mutations, particularly in pediatric cases and those associated with neurofibromatosis type 1 (NF1)[19–23]. NF1 typically manifests at birth or gradually over time, and its severity varies among individuals. Given that my 64-year-old patient has not exhibited typical signs of neurofibromatosis type 1 (NF1), such as café au lait spots, soft lumps under the skin, or unusual clusters of freckles, he is unlikely to have this condition. Secondly, KIT and PDGFRA mutations are mutually exclusive, and only 5–6% of GIST patients harbor PDGFRA D842V mutations[31]. Therefore, he likely harbors a KIT mutation that is sensitive to imatinib. The estimation of recurrence risk following the resection of a GIST is crucial in determining the need for adjuvant imatinib therapy. This assessment is based on various clinical characteristics, including tumor size, mitotic rate, primary tumor site, the presence or absence of tumor rupture, and the completeness of resection. The Armed Forces Institute of Pathology (AFIP) prognostic model, commonly utilized in the United States, categorizes tumors into no-, low-, intermediate-, or high-risk for recurrence based on these factors. In our case, the mitotic count was greater than 5 mitoses per 50 high-power fields, indicating a high mitotic rate. Considering that our patient likely harbors an imatinib-sensitive mutation and the high-risk nature of the tumor based on the evaluation of recurrence risk factors, it is essential to recommend adjuvant imatinib therapy. We thoroughly discussed with our patient, addressing all relevant issues, including the potential benefits and risks associated with imatinib treatment. Eventually, he agreed to undergo 3 years of adjuvant imatinib therapy, primarily covered by health insurance.

In the setting of metastatic GISTs, a multimodal approach involving systemic therapy and surgical intervention is often necessary. Neoadjuvant systemic therapy, such as imatinib, is preferred over initial surgery for potentially resectable metastatic

GISTs, enabling tumor reduction and facilitating subsequent surgical resection. However, surgery is generally reserved for cases demonstrating response to systemic therapy or primary resistance to imatinib. For patients with unresectable disease or disease, refractory to standard therapies, targeted agents like sunitinib or regorafenib offer alternative treatment options, carefully considering individual patient characteristics and tumor molecular profile.

Prognosis

According to current guidelines, prognostic factors include the mitotic rate, tumor size, tumor site, and the independent risk factor of tumor rupture. As reported by the Surveillance, Epidemiology, and End Results (SEER) program, data from patients diagnosed with GIST between 2012 and 2018 showed that the 5-year relative survival rates vary significantly based on stage: 95% for localized, 84% for regional, and 52% for distant cases, with an overall rate of 85% across all SEER stages combined[32]. Previous studies have indicated that extra-gastrointestinal stromal tumors' risk classification and prognosis (EGISTs) are notably poorer than GIST[33,34].

Limitation

This was the first case of primary liver GIST that we approached at our center, so the choice of approach, diagnosis, and treatment options is still limited. Regarding diagnosis, screening for GIST in other locations of the digestive tract, such as the small intestine, was currently limited. In terms of treatment, an open procedure was chosen to ensure the tumor does not rupture because we do not have much experience with laparoscopic surgery; this can be performed at centers with more experience.

Conclusion

This case highlights the need for multidisciplinary consultation in managing primary GISTs of the liver. Accurate diagnosis, surgical expertise, and personalized adjuvant therapy are crucial for better patient outcomes. Further research is necessary to enhance our understanding of prognostic factors and treatment strategies for these rare tumors.

Ethical approval

This study was conducted with the informed consent of patient and received the requisite ethical approval from the Scientific Council of Vietnam National Cancer Hospital. The council comprises expert representatives from relevant specialties, including hepatobiliary surgeons, radiologists, oncologists, gastroenterologists, and pathologists. Their comprehensive review and endorsement ensured adherence to the highest ethical standards throughout the research process. Our procedures adhered to the Declaration of Helsinki. The authors reported no conflicts of interest.

Consent

The patient agreed to participate in the study and was periodically re-examined by appointment. Written informed consent was obtained from the patient for publication and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Source of funding

None.

Author contribution

Conceptualization: A. Tuan Pham. Data curation: all authors. Methodology: all authors. Visualization: all authors. Writing—original draft: A. The Pham. Writing—review and editing: all authors.

Conflicts of interest disclosure

The author declares no conflicts of interest.

Research registration unique identifying number (UIN)

Our procedures adhered to the Declaration of Helsinki. This article was registered in "ResearchRegistry.com" with identifying number being "researchregistry10109".

Guarantor

Anh The Pham.

Data availability statement

None.

Provenance and peer review

None.

Patient perspective

The patient was satisfied with the treatment and postoperative care.

References

[1] Miettinen M, Lasota J. Gastrointestinal stromal tumors—definition, clinical, histological, immunohistochemical, and molecular genetic features and differential diagnosis. Virchows Arch Int J Pathol 2001;438:1–12.
[2] Miettinen M, Sarlomo-Rikala M, Lasota J. Gastrointestinal stromal tumors: recent advances in understanding of their biology. Hum Pathol 1999;30:1213–20.
[3] Beltran MA, Cruces KS. Primary tumors of jejunum and ileum as a cause of intestinal obstruction: a case control study. Int J Surg Lond Engl 2007;5:183–91.
[4] Søreide K, Sandvik OM, Søreide JA, *et al*. Global epidemiology of gastrointestinal stromal tumours (GIST): a systematic review of population-based cohort studies. Cancer Epidemiol 2016;40:39–46.
[5] Qian XH, Yan YC, Gao BQ, *et al*. Prevalence, diagnosis, and treatment of primary hepatic gastrointestinal stromal tumors. World J Gastroenterol 2020;26:6195–206.
[6] Fletcher CDM, Berman JJ, Corless C, *et al*. Diagnosis of gastrointestinal stromal tumors: a consensus approach. Int J Surg Pathol 2002;10:81–9.

[7] Sohrabi C, Mathew G, Maria N, *et al*. The SCARE 2023 guideline: updating consensus Surgical CAse REport (SCARE) guidelines. Int J Surg Lond Engl 2023;109:1136–40.
[8] Bhoy T, Lalwani S, Mistry J, *et al*. Primary hepatic gastrointestinal stromal tumor. Trop Gastroenterol Off J Dig Dis Found 2014;35:252–3.
[9] Hu X, Forster J, Damjanov I. Primary malignant gastrointestinal stromal tumor of the liver. Arch Pathol Lab Med 2003;127:1606–8.
[10] Joyon N, Dumortier J, Aline-Fardin A, *et al*. Gastrointestinal stromal tumors (GIST) presenting in the liver: diagnostic, prognostic and therapeutic issues. Clin Res Hepatol Gastroenterol 2018;42:e23–8.
[11] Lok HT, Chong CN, Chan AWH, *et al*. Primary hepatic gastrointestinal stromal tumor presented with rupture. Hepatobiliary Surg Nutr 2017;6:65–6.
[12] Fortman BJ. Torricelli-Bernoulli sign in an ulcerating gastric leiomyosarcoma. AJR Am J Roentgenol 1999;173:199–200.
[13] Levy AD, Remotti HE, Thompson WM, *et al*. Gastrointestinal stromal tumors: radiologic features with pathologic correlation. Radiogr Rev Publ Radiol Soc N Am Inc 2003;23:283–304; 456; quiz 532.
[14] Yu MH, Lee JM, Baek JH, *et al*. MRI features of gastrointestinal stromal tumors. AJR Am J Roentgenol 2014;203:980–91.
[15] Van den Abbeele AD. The lessons of GIST--PET and PET/CT: a new paradigm for imaging. The Oncologist 2008;13(Suppl 2):8–13.
[16] Kim SJ, Lee SW. Performance of F-18 FDG PET/CT for predicting malignant potential of gastrointestinal stromal tumors: a systematic review and meta-analysis. J Gastroenterol Hepatol 2018;33:576–82.
[17] Miettinen M, Sobin LH, Sarlomo-Rikala M. Immunohistochemical spectrum of GISTs at different sites and their differential diagnosis with a reference to CD117 (KIT). Mod Pathol Off J U S Can Acad Pathol Inc 2000;13:1134–42.
[18] Medeiros F, Corless CL, Duensing A, *et al*. KIT-negative gastrointestinal stromal tumors: proof of concept and therapeutic implications. Am J Surg Pathol 2004;28:889–94.
[19] Janeway KA, Liegl B, Harlow A, *et al*. Pediatric KIT wild-type and platelet-derived growth factor receptor alpha-wild-type gastrointestinal stromal tumors share KIT activation but not mechanisms of genetic progression with adult gastrointestinal stromal tumors. Cancer Res 2007;67:9084–8.
[20] Théou-Anton N, Tabone S, Brouty-Boyé D, *et al*. Co expression of SCF and KIT in gastrointestinal stromal tumours (GISTs) suggests an autocrine/paracrine mechanism. Br J Cancer 2006;94:1180–5.
[21] Miettinen M, Fetsch JF, Sobin LH, *et al*. Gastrointestinal stromal tumors in patients with neurofibromatosis 1: a clinicopathologic and molecular genetic study of 45 cases. Am J Surg Pathol 2006;30:90–6.
[22] Mussi C, Schildhaus HU, Gronchi A, *et al*. Therapeutic consequences from molecular biology for gastrointestinal stromal tumor patients affected by neurofibromatosis type 1. Clin Cancer Res Off J Am Assoc Cancer Res 2008;14:4550–5.
[23] Yamamoto H, Tobo T, Nakamori M, *et al*. Neurofibromatosis type 1-related gastrointestinal stromal tumors: a special reference to loss of heterozygosity at 14q and 22q. J Cancer Res Clin Oncol 2009;135:791–8.
[24] Heinrich MC, Corless CL, Duensing A, *et al*. PDGFRA activating mutations in gastrointestinal stromal tumors. Science 2003;299:708–10.
[25] Hirota S, Ohashi A, Nishida T, *et al*. Gain-of-function mutations of platelet-derived growth factor receptor alpha gene in gastrointestinal stromal tumors. Gastroenterology 2003;125:660–7.
[26] Novelli M, Rossi S, Rodriguez-Justo M, *et al*. DOG1 and CD117 are the antibodies of choice in the diagnosis of gastrointestinal stromal tumours. Histopathology 2010;57:259–70.
[27] Miettinen M, Wang ZF, Lasota J. DOG1 antibody in the differential diagnosis of gastrointestinal stromal tumors: a study of 1840 cases. Am J Surg Pathol 2009;33:1401–8.
[28] Rubin BP, Fletcher JA, Fletcher CDM. Molecular Insights into the Histogenesis and Pathogenesis of Gastrointestinal Stromal Tumors. Int J Surg Pathol 2000;8:5–10.
[29] National Comprehensive Cancer Network. Gastrointestinal Stromal Tumors (Version 1.2024). Accessed 8 March 2024. https://www.nccn.org/professionals/physician_gls/pdf/gist.pdf.
[30] Casali PG, Blay JY, Abecassis N, *et al*. Gastrointestinal stromal tumours: ESMO–EURACAN–GENTURIS Clinical Practice Guidelines for diagnosis, treatment and follow-up. Ann Oncol 2022;33:20–33.
[31] Jones RL, Serrano C, Mehren M von, *et al*. Avapritinib in unresectable or metastatic PDGFRA D842V-mutant gastrointestinal stromal tumours: long-term efficacy and safety data from the NAVIGATOR phase I trial. Eur J Cancer 2021;145:132–42.
[32] Zhang H, Liu Q. Prognostic indicators for gastrointestinal stromal tumors: a review. Transl Oncol 2020;13:100812.
[33] Survival Rates for Gastrointestinal Stromal Tumors. The American Cancer Society medical and editorial content team. Accessed 17 March 2024. https://www.cancer.org/content/dam/CRC/PDF/Public/8641.00.pdf.
[34] Xu L, Zhang M, Xu M. Primary hepatic gastrointestinal stromal tumor with right adrenal gland invasion: a case report and systematic literature review. Medicine (Baltimore) 2019;98:e15482.